EXPERIENCES WITH GIN PROCESS CONTROL IN THE MIDSOUTH AND WEST

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ABSTRACT. *Various components of a computerized process control system, such as infrared moisture meters, video cameras, computers, paddle samplers, pneumatic cylinders, etc., were installed in a phased approach over a five-year period at two commercial cotton gins. The systems are not yet fully automated or fully implemented, but all of the components that have been evaluated functioned well for extended periods of time. Analyses indicate that reducing the number of lint cleaners from two to one on cotton selected by the computerized system could increase the bale value by about \$3 to \$6 each. Controlling moisture correctly could have a similar impact and a savings of about \$6 per bale. Total additional profits for cotton grown in the United States could exceed \$135 million annually.* **Keywords.** *Cotton, Ginning, Automation, Fiber quality, Gin economics.*

A computerized gin process control system (GPCS) was fully implemented in the Microgin at the USDA Cotton Ginning Laboratory at Stoneville, Mississippi, in 1989 (Anthony, 1990). The system consisted of three main components: (1) three sensing stations for measuring moisture, color, and trash, (2) computer software to collect and analyze the data and determine the optimum process sequence, (3) and in-line directional valves to instantaneously redirect the flow of cotton. This system is illustrated in figure 1. Each sensing station consisted of an infrared moisture meter manufactured by Infrared Engineering of Waltham, Massachusetts (Anthony, 1991) and a video camera manufactured by Motion Control, Inc., of Dallas, Texas, (Anthony, 1989) to measure color and trash. A compression ram was installed at the feed control and at the hopper above the extractor-feeder to compress the cotton against the sensors to improve the accuracy of the sensors. (Anthony and McCaskill, 1989). At the battery condenser, an internal shroud was added to reduce the volume available for the cotton to occupy and thus increase the cotton density sufficiently to allow the sensors to operate correctly. The microgin process control system was operated extensively at temperatures from 10° to 45° C and in humidities of 35 to 85% and all sensors functioned correctly. The equipment that operates in the laboratory must often be modified extensively before it will function acceptably in a commercial environment.

Article was submitted for publication in June 1994; reviewed and approved for publication by the Food and Process Engineering Inst. of ASAE in November 1995. Presented as ASAE Paper No. 94-1017.

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PURPOSE

The purpose of this article is to describe the experiences involved in the phased evaluation of a process control system in two commercial gin systems.

METHOD

Equipment similar to that which was used in the Microgin was installed in a commercial gin in a phased approach beginning with the infrared moisture meters and increasing each year until most of the system was available (Anthony and Byler, 1994).

BURDETTE GIN, LELAND, MISSISSIPPI

1989. Two infrared moisture meters were installed in 1989, one at the feed control and one at the extractor-feeder. These two locations were chosen because the cotton was relatively stationary in both, and the density of the cotton was higher than in most other places in the seed

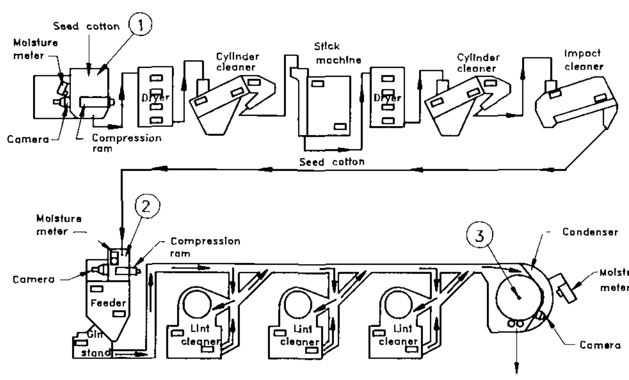

Figure 1–Schematic of a small-scale ginning system with compression devices and sensors installed at the feed control (1), above the extractor-feeder (2), and condenser (3).

cotton portion of the ginning system. At the feed control, the infrared moisture meter was installed above the feed rollers and thus had several feet of cotton above the cotton that the sensor was viewing to provide compression. At the extractor-feeder, the moisture meter was installed in the lower part of the hopper. The screw conveyor in the conveyor-distributor forced cotton down into the hopper which increased its density sufficiently for the infrared moisture meter to respond. The infrared moisture meters worked without operational problems. Samples were taken periodically throughout the season and compared to oven moistures to verify the calibration of the meters.

1990. After the gin was extensively modified as a part of a major rebuilding program, two infrared moisture meters were again installed at the feed control and the extractor-feeder as in 1989. Two color/trash sensing stations were also installed, one in the hopper immediately above the number 2 extractor-feeder/gin stand, and the other prior to the battery condenser. A compression ram similar to the one used in the Microgin was used in the extractor-feeder area (Anthony and McCaskill, 1992). The compression ram operated continuously for 24 h per day for about 10 weeks without problems. The chamber that contained the camera, power supplies, and related hardware was installed in a manner to allow it to swing away from the hopper to allow calibration without stopping the gin machinery. Although the internal shroud installed at the battery condenser in the Microgin worked well, its use in a commercial-sized condenser was questionable. As a result, a separate device was designed and constructed that extracted a sample of cotton from the lint flue, compressed it against the sensors and then returned it to the lint flue (Anthony and McCaskill, 1991). The device (fig. 2) consisted of a specially designed valve to allow continuous or intermittent extraction of lint from the lint flue, a fan and pipe to vacuum the cotton from the lint flue, a condenser to form the lint into a batt, a lint slide to allow the batt to flow down, and a pair of rollers to meter the cotton back into the lint flue a few feet from where it was extracted. The video camera and infrared moisture meter were installed on the underside of the lint slide, and a specially designed, octagon-shaped cylinder was used to compress the sample against the sensors. The off-line sampler was operated only while an attendant was present because of its complexity. It operated successfully throughout the season but since it has a large number of moving parts and is very expensive to construct, alternatives to it were later developed.

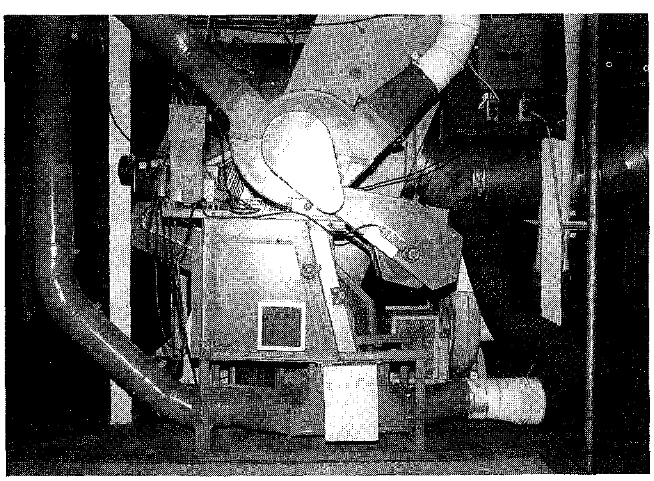

Figure 2–Device to automatically and continuously extract cotton from a lint duct, condense the cotton, measure moisture, color and trash properties, and return the cotton to the air stream at a commercial gin.

The only problems encountered with the entire process control system were the difficulty in predicting the correct color of the cotton based upon the seed cotton measurements before the extractor-feeder, and the fact that when the number 2 gin stand was not operating no data was available for moisture, color, or trash. The color problem was resolved by moving the sampling station to immediately before the first lint cleaner rather than before the extractor-feeder so that the camera would be viewing lint; the problem with the potential for the gin stand to be inoperative was circumvented by defaulting to the next sensing station when necessary. This necessitated development of a new device called a paddle sampler (fig. 3) (Anthony, 1992). The paddle sampler worked so well that the off-line sampler extraction device was also replaced with a paddle sampler in subsequent years.

1991. Another major gin renovation project which included a new foundation as well as new gin stands and lint cleaners and the associated ductwork necessitated building new samplers in 1991. The sensors were installed in the same locations as they were in the previous year. Again the system operated without significant problems although they continued to require minor technical assistance from USDA personnel.

1992. One of the changes in 1992 from 1991 was that the sampling station behind the gin stand was rebuilt and installed on the opposite side of the lint duct to facilitate calibration of the instruments. The sampling station before the battery condenser was also replaced because a new lint duct was installed. The second infrared moisture meter was moved to immediately before the second stage of cylinder cleaning and installed in a paddle sampler. This change ensured that a valid cotton sample was always available.

1993. Prior to 1993, one or more computers (three in 1992) were used to collect and analyze the data from the sensors. In 1993, the computers that were used to collect the data from the infrared moisture meter, the computer that was used to collect and analyze the data from the color/trash sensor, and the computer that was used to

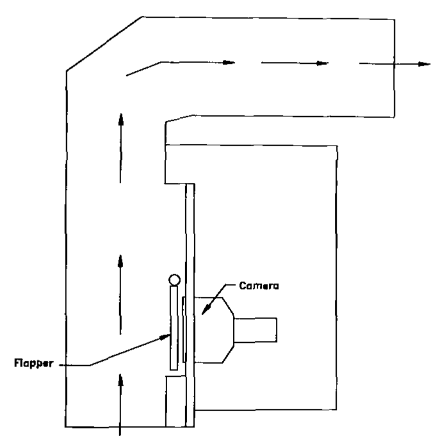

Figure 3–Schematic of the perforated, flapper-type device used to collect and increase the surface density of cotton.

determine the optimum process sequence were replaced by a single computer. This consolidation was made possible by rewriting all software into one C-language program. The other major change was that directional valves between the lint cleaners were automated by installing pneumatic cylinders, solenoids, position sensors, programmable logic controllers (PLC), etc., to allow the ginner to select a new sequence of machines simply by pushing a button. The PLC-based system automatically disengaged the gin stand, paused to allow the cotton to clear the ducts, changed the valves to the correct setting, verified the position of all valves, and signaled the ginner to re-engage the gin stand. This operation took about 15 s per gin stand and was done sequentially so that the gin would not come to a complete stop at any one time, but rather would be reduced in throughput by one-third. Both of these improvements performed in a superb fashion.

Directional Valves. The optimum valving system before each machine, including seed cotton cleaners and lint cleaners, is one that will allow continuous and on-line redirection of the cotton through various machines without stopping the machines or the flow of cotton. This type of valve has been installed in the Microgin and in the full-scale gin at the U.S. Cotton Laboratory in Stoneville, Mississippi. These valves can instantaneously redirect the flow of cotton without an interruption in ginning. At Burdette Gin, Leland, Mississippi, pneumatic cylinders were installed on each valve leaf in the Lummus five-way directional valve between the lint cleaners to allow the ginner to activate a switch that would throw all of the leafs in the correct direction to achieve either zero, one, or two lint cleaners. Solenoids are used to activate the pneumatic cylinders and those solenoids require a signal before they move, which prevents a power failure from causing chokeups. Position sensors are also installed on each pneumatic cylinder to ensure that the cylinders are in the correct position before the gin stand is engaged again. Although this system is considerably less expensive than the continuous on-line system, it does require a 10 to 15 s downtime while the valves are switched. Since the marketing system discounts cotton that has not received lint cleaning, the zero option was defaulted to one lint cleaner. About 80% of the cotton required only one stage of lint cleaning, however, control actions were not executed at Burdette Gin.

Data. Each year data were collected with a microcomputer on a continuous, 24-h basis throughout the season. The data consisted of moisture content, color, trash, number of lint cleaners, and related information. About 10 color and trash readings were taken per bale at each sensor location (one before and one after lint cleaning). Data was analyzed with SAS using frequency and regression procedures. Data collected during the season were compared to the official Agriculture Marketing Service (AMS) classification to determine how well the measurements taken at the gin correlated to similar measurements by AMS. These measurements were not on the same sample but were generally from the same bale of cotton.

Westlake Gin, Stratford, California

1992. When Westlake gin was constructed in 1984, infrared moisture meters were installed in several locations. As a result of functional problems related primarily to improper installation, the meters were not fully utilized until 1992. The meters were modified and installed according to manufacturers' guidance to improve their utility. Three infrared moisture meters were used to scan the moisture content of the cotton fiber. The first infrared meter scanned the incoming cotton and the other two infrared meters were located above the gin stands. The output from these two meters were averaged together to produce a more reliable input variable for control of the drying process.

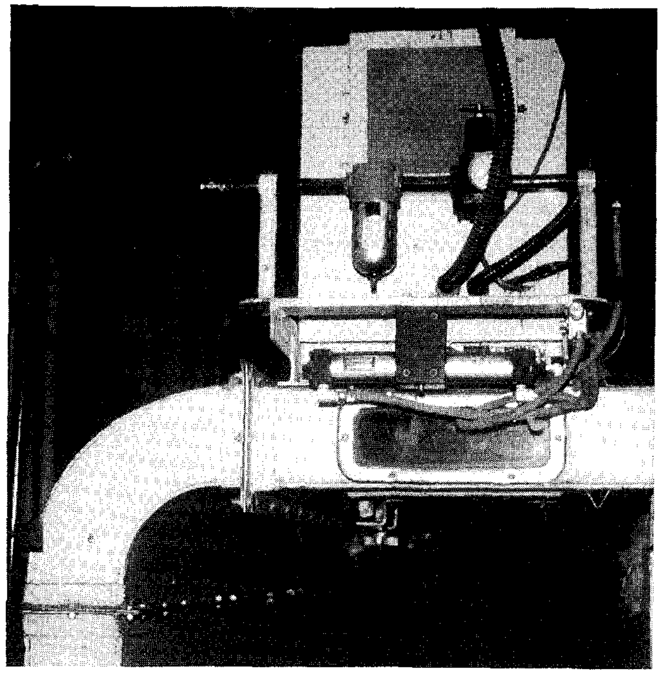

Figure 4–Color/trash sensor and sampler installed behind the gin stand at Westlake Gin.

In addition, color/trash sensors and paddle samplers were installed behind a gin stand (fig. 4) and before the battery condenser (fig. 5). Data were collected and analyzed by a separate computer via an analog-to-digital

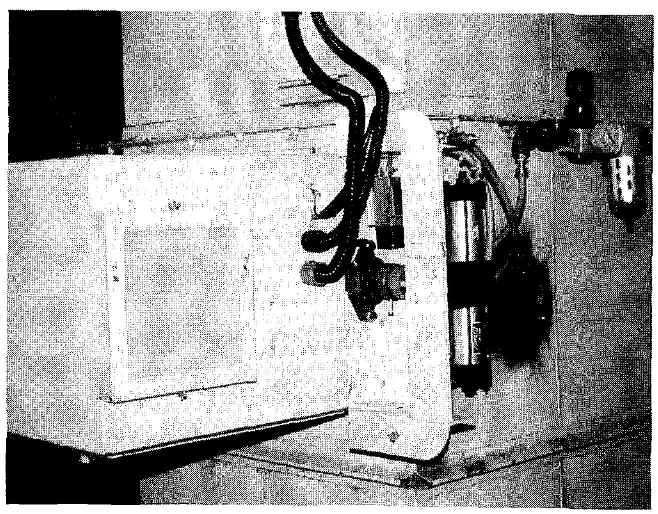

Figure 5–Color/trash sensor and sampler installed before the battery condenser at Westlake Gin.

board and a framegrabber board. Data were used for validation purposes only and machine sequences were not changed as a result of computer measurements of color and trash.

1993. An additional color/trash sensor and paddle sampler was installed between the module feeder and the first dryer in 1993. Pneumatic cylinders were also installed on the shaft of each valve leaf between the lint cleaners to automate the selection of number of lint cleaners. Two lights were installed at the control console to indicate to the gin operator the number of lint cleaners recommended by the process control system. The computer made recommendations on the number of lint cleaners to use and gin personnel made the final decision by engaging a switch located at the gin console to activate a pneumatic cylinder and a series of timers to change the number of lint cleaners. This reduced the chance of valve switching errors and resulted in a downtime of 7 to 10 s. The system recommended one lint cleaner about 85% of the time and the ginner followed the recommendation the majority of the time. The first two bales of a module were used to ascertain the recommendation for the remaining 12 bales. Control actions were taken at Westlake Gin for the entire season.

Data from 42,000 bales of California SJ2 and M5 cotton were used to evaluate the system. The color and trash grades were compared to current pricing structures and a lint cleaner recommendation computed.

Data. Data were collected with a microcomputer on a continuous, 24-h basis throughout the season. The data consisted of moisture content, color, trash, lint cleaner value, and related information. From four to six color and trash readings were taken per bale at each of two sensor locations in 1992—one before and one after lint cleaning. In 1993, data were also collected at the station before the first dryer. Data collected during the season were compared to the official AMS classification after each 50-bale segment and at the end of the season with SAS using frequency and regression procedures. Data were analyzed based on the price schedules of the Commodity Credit Corporation (CCC) as well as Calcot, a cooperative merchant. Two price schedules were used to illustrate the impact of different prices for cotton.

Results and Discussion

Burdette Gin, Leland, Mississippi

Correlation between measurements made by the computer system and measurements made at the classing office were relatively close. Note that comparisons for color are based on instrument measurements at the gin and operator measurements at the AMS. The computer system took a reading every 10 s or so and had a number of readings per bale, compared to only two that were obtained at the AMS classing office. For manual classing, an operator "makes a face" on the sample and produces a different appearance than that seen by the video camera. Data collected in 1992 and compared with official (manual) classification for color and trash established by the USDA AMS indicated good correlation. Similar results were achieved in 1993. These data were sufficiently similar to the AMS data so that the process control decision was correct.

Based on the sensor measurements in 1993 before the battery condenser, 22.6, 66.7, and 5.7% of the bales were classed color 31, 41, and 51, respectively; for the official AMS manual classification these same values were 58.6, 33.3, and 0.1% (Anthony et al., 1994). Color grade was the same in the gin and AMS for 40% of the bales and was one grade too low at the gin 56% of the time and one grade too high 5.5% of the time. The remaining 5 to 8% of the bales were classed as other less common color grades. The disagreements between AMS and gin measurements is likely due to insufficient sample size at the gin. In addition, the comparisons are between a manual classer in AMS and an instrument at the gin.

In terms of classers leaf, 41.4% of the bales were assessed the same at the gin and AMS, and 49.6% differed by one leaf grade. The gin sensor estimated 41.1% of the bales one leaf grade too high (too trashy) and 8.5% too low (clean). Neither the gin sensing system or the AMS system actually measure classers' leaf, it is a visual interpretation by a cotton classer. Thus, a tabular algorithm provided by AMS was used to convert trash area data from the sensor to classers' leaf data; the algorithm is not very accurate. The area of the sample viewed by the camera that contains trash is a better comparison, however, the "official" leaf grade is provided by the classer. For the 1993 data, 80.2% of the readings for percent trash area were within ± 0.1 which is the value used by AMS for sustainment purposes. This correlation was better than the 75% between two AMS instruments. Additionally, 92% of the bales were within ± 0.2%.

The utility of the process control system can best be demonstrated by looking at the color and leaf distribution for the grades for the bales produced in the 1993 season. At Burdette, over 58% of the bales were classified color 31, leaf 4 or better by AMS. For those bales one stage of lint cleaning could have been deleted and the moisture content could have been raised. The monetary impact of using only one stage of lint cleaning would be to add about 5 to 10 lb of cotton to the bale without significantly reducing the overall bale value. The leaf grade would likely indicate a higher trash level, but not sufficiently to decrease the bale value enough to negate the increase due to the additional weight. In terms of moisture content, it is likely that at least one, perhaps two percentage points of moisture should have been left in the cotton and the bale weight thus increased 5 to 10 lb. The combined total from leaf and moisture corrections would be 10 to 20 lb of bale weight, a value of $6 to $12 per bale. A similar statement can be made for the 22% of the bales that were graded color 41 and leaf 3 or better. With a properly functioning process control system, profits to the farmers would have increased by at least $100,000 for the 16,655 bales ginned. Savings to the gin in terms of fuel would have been about $12,000.

Westlake Gin, Stratford, California

Based on sensor measurements on cotton immediately before the battery condenser, 27.2, 39.8, 9.8, 7.2, and 16%, of the bales were classed as color 21, 31, 41, 42, and other respectively; for the official AMS classification, these values were 60.4, 34.3, 0.3, 0.0, and 5.0% (Scamardo, 1994). Color grade was the same at the gin and AMS 36.6% of the time, and exactly one grade lower 58% of the time. For the other 5.4% of the bales, the grades differed by less than one grade. Correlation of the data was much better at Westlake Gin than at Burdette Gin, possibly due to the greater uniformity of color in the California growth region.

In terms of classers leaf, 49.2% of the bales were assessed the same at the gin and AMS while 91.8% were within one leaf grade with the tendency for the gin to assign a higher (more trash) leaf value. The calculated percent area measured at the gin was within 0.1% of the value assigned at AMS 50.6% of the time. This correlation was not as good as the 75% expected between two AMS instruments; however, 81.7% of the time the gin values were within 0.2% of the AMS value.

The 1993 data supported using one lint cleaner on the majority of the cotton. The value of the increased weight of saleable cotton, resulting from only one lint cleaning was greater than the reduction in price associated with the higher leaf grade that occurred some of the time. Price determined from the CCC loan chart netted an average increase in value of $3 per bale. Annually this could gross an additional $126,000 at a 42,000-bale gin.

Generally, the lint cleaning decision avoided the sharp price break between leaf grades 5 and 6 for color 31 on the CCC loan chart. The price schedule for Calcot had a sharp break between leaf 3 and 4. Calculations similar to those with the CCC loan prices indicated an increase in profits of $2.35 per bale. To avoid the sharp price break that occurred in both price schedules, decisions were conservatively made in reducing the level of lint cleaning.

Drying. Standard drying practice sets a constant temperature and allows fiber moisture to vary. Depending on the moisture content of incoming cotton, this typically leads to over- or underdrying. Varying the drying temperature during processing results in a more desirable and stable fiber moisture content. The elimination of human error in overdrying could potentially yield at least a 1% increase of bale weight or $3 per bale. In addition, a fuel savings of about 50% or $0.60 per bale would occur.

Conclusion

Computerized process control systems can be used to instantly determine the quality of the cotton as it is processed. Under normal situations it is possible to net over of $6 per bale by controlling drying temperatures and the number of lint cleaners used. For less than ideal situations where the color and leaf grade of the cotton varies substantially, profits would be increased considerably more.

Problems

After several years of experience with components of the process control system in a commercial gin, most of the problems have been solved. The major problem that remains is the requirement that the sensors be calibrated for color and trash every 4 h of operation to comply with industry standards. At Burdette Gin, USDA personnel did virtually all of the calibration which was time consuming and was done only within normal working hours. As a result, no more than 8 h of valid data were collected each day. Another problem is that the current camera system cannot determine whether bark or grass is present in the sample. The presence of bark or grass will likely change the decision due to the penalty associated with them. The same holds true for the condition called "preparation". The term "preparation" or "prep" is used to indicate the lack of smoothness of the sample. As the number of lint cleaners and the amount of drying are reduced, the cotton has less of a combed and blended appearance and thus a higher tendency to be identified as a "prep bale". A prep classification may reduce the value of the bale in the market place. Research must be conducted to clearly indicate that "preparation" due to reduced lint cleaning does not impact the processing of cotton at the textile mill. In the present classing system, the term "preparation" is used to classify cotton as being roughly processed; however, properly processed cotton can also have a similar appearance.

Concerns

One of the concerns is deciding which market price schedule to use because different market price schedules will produce a different optimum process sequence for cotton. For instance, in the 1993 CCC prices, a big break occurred between leaf 5 and 6 for color 31 and between leaf 4 and 5 for color 41. However, in the Calcot price schedule, the big break for color 31 comes between leaf 3 and 4; thus, cleaner cotton is required by Calcot. There is flexibility in the current control software to allow for different price schedules but the control decision rules must be developed by other computer programs such as reported by Anthony et al. (1982). The gin manager must decide on the price schedule before the cotton is processed in order that optimum control decisions can be made.

Another concern is the synchronization of the bale number and the readings from the cameras at the color and trash sensing stations. The camera at the battery condenser is only slightly out of phase with the bale number, but perhaps out of phase enough to cause one of the samples from the bale to actually belong to the subsequent bale and perhaps be incorrect at classing. The camera before the first lint cleaner is always out of phase with the camera at the battery condenser and it is very difficult to correlate that data. From an actual operation of the process control system, this is not a problem as long as the color and leaf grades determined by the gin system are sufficiently close to the official AMS grades for a particular bale so that the correct machinery decision can be made. Thus, it is imperative that the gin and AMS sensors remain calibrated.

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